Burn Injuries in Children and the Use of Biological Dressings

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Abstract: Burns represent a significant cause of morbidity and mortality in children. In this article, a case discussion will serve as a platform for discussing the evaluation and treatment of burns in children. Use of various burn dressings such as hydrocolloids, polyurethane films, hydrogels, biosynthetic skin dressing, and biological dressings will be discussed.

Key Words: burns, biological dressings, hydrocolloids

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TARGET AUDIENCE

This CME activity is intended for physicians who care for children. Pediatricians, emergency physicians, pediatric emergency physicians, and surgeons will find this information especially useful.

LEARNING OBJECTIVES

After completion of this article, the reader should be able to:

1. Manage burn injuries in children in the acute phase including identification of burn severity, estimation of body surface area involvement, and fluid resuscitation calculation.
2. Facilitate the rejuvenation of new skin and promote wound healing using biologic burn dressings.

CASE 1

A 3-year-old boy found hiding under a couch during a house fire is brought into the emergency department (ED) by EMS. He is awake but appears sleepy and has a soft hoarse cry.

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Vital Signs

Temperature is 38°C; blood pressure is 72/45 mm Hg; heart rate is 132 beats/min; respiratory rate is 37 breaths/min, and pulse oximetry reads 95% on room air.

Physical Examination

His face is covered in soot; there is black-crusted material in his nostrils, and his eyebrows are singed. His lung sounds are clear. The heart examination reveals tachycardia but is otherwise normal, and he demonstrates no abdominal tenderness. Exposure of his body reveals red confluent burns with thick blisters intermixed with whitish patches on his left arm, and his left leg and left foot are pale, appearing white and waxy. There are no obvious bony deformities and no active bleeding. Total body surface area (TBSA) with partial- and full-thickness burns is estimated at 25%.

Medications

He takes no medications and is fully immunized. He has no known allergies.

1. How do you quantify the severity of burns in children?
2. What are the initial steps in management of burn injuries?
3. Which patients require referral to a burn center?
4. What dressings are available to treat burns in the ED?

PEDIATRIC BURN INJURIES

Burns represent the second most frequent cause of traumatic death in children younger than 5 years resulting in 1000 to 5000 pediatric deaths and approximately 30,000 hospitalizations per year.[1] Younger children are particularly vulnerable because of their physiologic limitations in handling the stress of fluid shifts resulting from burn injuries, and burns exceeding 20% TBSA carry a higher mortality rate (9.9%) in children younger than 3 years.[2] Although burns can be the results of contact with hot objects, electricity, and chemical or radiation exposure, flame (as in a house fire) or flash burns account for nearly half of all burn injuries. Scalds are the most common etiology of burns in patients younger than 5 years and the second most common type of burn in all age groups.[3]

Duration of exposure and heat exchange contribute to depth of burn. Scalding by grease or liquid heated in a microwave is particularly dangerous as it may cause third-degree burns. Water heaters should be adjusted in families with young children, as the time to cause burns from exposure to hot water from sinks and bathtubs can be seconds at temperatures greater than 56°C (133°F).[3] Although the US Consumer Safety Commission recommends that residential water heaters be set at no more than 120°F (48°C), an infant or child may sustain second-degree burns if left in water at this temperature for more than a minute. Therefore, a safe temperature for bathing a baby is a temperature of 100°F (Table 1).[4]

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TABLE 1. Time and Temperature Relationship to Severe Burns

Water	Temperature	Time for a Third-Degree Burn to Occur
155°F	68°C	1 s
148°F	64°C	2 s
140°F	60°C	3 s
133°F	56°C	15 s
127°F	52°C	1 min
124°F	51°C	3 min
120°F	48°C	5 min
100°F	37°C	Safe temperature for bathing

Adapted from American Burn Association. Scald Injury Prevention Educator's Guide. Available at: www.ameriburn.org/Preven/ScaldInjuryEducator'sGuide.pdf. Accessed January 2, 2012. Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.

Ten percent to 20% of children admitted for burns suffered injuries as a result of child abuse.[5] Burns of nonaccidental trauma should be suspected in patients presenting with patterned burns such as demonstrated in Figure 1 from an iron. Children forced to sit in a hot tub may show areas of sacral sparing where their skin was pressed against by the relatively protective cooler tub base (Fig. 2).

PATHOPHYSIOLOGY

Understanding burn pathophysiology is important to the estimation of severity and approach to treatment. The skin is composed of 2 layers, the epidermis and the dermis. The epidermis serves as a vapor barrier, maintaining body fluid and moisture and protecting against infection. Beneath the epidermis, the dermal layer cushions against mechanical trauma and provides for the elasticity and mechanical integrity of the skin.[6] Blood vessels run within the dermis and extend into the dermal papillae, providing nutrition. Beneath the dermis is the subcutaneous fat, which contains free nerve endings and the roots of hair follicles.

Burns are classified as first, second, or third degree in depth. Changes in skin appearance on presentation are the cornerstone

FIGURE 1. Patterned burn from an iron in an infant caused by child physical abuse (photo courtesy of Carol Berkowitz, MD).

FIGURE 2. Immersion burn caused by child physical abuse (photo courtesy of EMSC Slide Set).

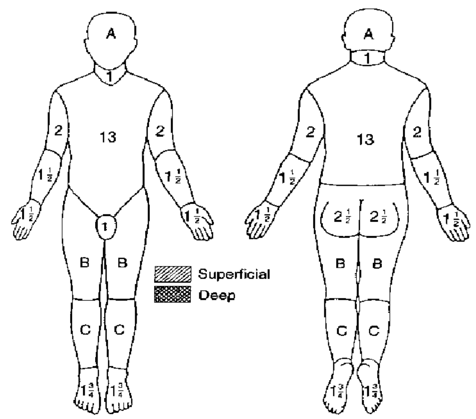
of burn identification; however, burns may evolve and appear to deepen over a 24- to 36-hour period after initial injury.[4] First-degree burns involve only the epidermis and have a confluent red appearance with an absence of blisters. These burns are not normally considered in calculations of TBSA burned because they have minimal physiologic consequences, but they may be important to document from a legal standpoint. Second-degree burns are classified as superficial partial-thickness or deep partial-thickness depending on depth of extension into the dermis. Superficial partial-thickness burns involve the epidermis and superficial dermis, appear pink and moist, are blanching, and are extremely tender. Hair is usually intact, and there may be thin, fluid-filled blisters. Deep partial-thickness burns extend into the reticular (deep) dermis and may be intermixed with areas of third-degree burns. Characteristically red and white in appearance, nonblanching, and with thick blisters that commonly rupture, deep partial-thickness burns may or may not be painful; if sensation is intact, pain may be severe. Third-degree burns are full-thickness burns, which destroy both the epidermis and dermis. Because the dermal capillary network, including sweat glands and hair follicles, is also destroyed, third-degree burns appear dry, white, charred, or leathery, and the tissue has no sensation. Burns that extend through the subcutaneous tissue into underlying structures such as fascia, muscle, and bone are sometimes termed fourth-degree burns.

BURN SURFACE AREA ESTIMATION

Estimation of percent TBSA involvement is an important early step in burn management, serving as a guide for fluid needs and assisting the clinician in determining patient disposition and need for burn center referral. Total body surface area estimation can be challenging, and studies have shown significant variability among clinicians measuring the same burn. Use of an age-appropriate Lund and Browder chart provides a more accurate assessment than the simpler "rule of 9's," especially for children younger than 10 years (Fig. 3). A quick method to estimate TBSA is to recognize that the patient's hand (palm and fingers) covers approximately 1% of the patient's body surface area and to calculate accordingly.

Burn center referral recommendations published by the American Burn Association assist the clinician in determining need to transfer (Table 2). These criteria include TBSA (>10%), depth (any full thickness), high-risk locations (hands, feet, face, joints, genitalia, perineal), special types (chemical, electric,

Complete the table to calculate the total area of burn involved. (*Lund Browder Chart*)



Region	%
Head	
Neck	
Ant. Trunk	
Post. Trunk	
Right arm	
Left arm	
Buttocks	
Genitalia	
Right leg	
Left leg	
Total burn	

Relative percentage of areas affected by growth

Age (years)	0	1	5	10	15	Adult
A - 1/2 of head	9 1/2	8 1/2	6 1/2	5 1/2	4 1/2	3 1/2
B - 1/2 of one thigh	2 3/4	3 1/4	4	4 1/4	4 1/2	4 3/4
C - 1/2 of one leg	2 1/2	2 1/2	2 3/4	3	3 1/4	3

Patient Age_______________

Patient weight_____________**KG**

Time of Injury______________**AM/PM**

Allergies_______________________

Assess risk for inhalation injury and/or Carbon monoxide poisoning:	Consider early intubation if:	Other considerations:
❑ Enclosed space burn ❑ Flame burn ❑ Explosion ❑ Facial burn	❑ Stridor ❑ Hoarse voice ❑ Black tinged sputum ❑ Soot around face ❑ Singed eyebrows ❑ Labored respirations	❑ Remove all clothing and jewelry ❑ Cover burn with dry sheet ❑ Pulse oximetry monitoring ❑ Prevent hypothermia

FIGURE 3. Lund and Browder chart for determination of body surface area burned.

inhalation), and burns in children with special health care needs, although some centers may opt to manage selective burns instead of transfer to a burn center (ie, small burns to the hands or feet).

Patients with greater than 20% TBSA (and some with TBSA 10%–20%) will likely develop shock and require intravenous fluid resuscitation. Burn shock is multifactorial in origin. Direct tissue damage causes increased microvascular permeability in burned areas; generalized inflammation and release of mediators into the bloodstream contribute to increased microvascular permeability in unburned tissue as well. A loss of circulating plasma volume, decreased cardiac preload, and hypovolemia ensue. Meanwhile, systemic inflammation may also exert a depressive effect on myocardial contractility. These processes cause shock (the "ebb phase" of the response to injury), manifested by a

TABLE 2. Burn Center Referral Criteria

1. Partial-thickness burns of >10% of the total body surface area
2. Burns that involve the face, hands, feet, genitalia, perineum, or major joints
3. Third-degree burns in any age group
4. Electrical burns, including lightning injury
5. Chemical burns
6. Inhalation injury
7. Burn injury in patients with preexisting medical disorders that could complicate management, prolong recovery, or affect mortality
8. Any patients with burns and concomitant trauma (such as fractures) in which the burn injury poses the greatest risk of morbidity or mortality. In such cases, if the trauma poses the greater immediate risk, the patient's condition may be stabilized initially in a trauma center before transfer to a burn center. Physician judgment will be necessary in such situations and should be in concert with the regional medical control plan and triage protocols.
9. Burned children in hospitals without qualified personnel or equipment for the care of children
10. Burn injury in patients who will require special social, emotional, or rehabilitative intervention

These criteria serve as a guide for hospitals for transfer decisions for pediatric patients with burns but may not fully reflect common practice for tertiary care pediatric centers that may opt to manage selective burns instead of transfer to a burn center.

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TABLE 3. Intravenous Fluid Calculation Formulas for First 24 Hours of Resuscitation*†

Parkland formula	4 mL × patient's weight (kg) × % TBSA burned, given as LR solution. Half is given over the first 8 h after burn, and the remainder over the next 16 h
Galveston formula	LR at 5000 cm^3/m^2 × % TBSA + LR at 2000 cm^3/m^2 per 24 h. Half is given over the first 8 h after burn and the remainder over the next 16 h
Modified Brooke formula	2 mL × patient's weight (kg) × % TBSA burned given as LR solution. Half is given over the first 8 h after burn and the remainder over the next 16 h

*Adapted from Alvarado R, Chung KK, Cancio LC, et al. Burn resuscitation. *Burns.* 2009;35:4–14. Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.

†Additional glucose-containing maintenance fluids are required for the Parkland and modified Brooke formulas. At Galveston, serum glucose levels are closely monitored, and additional glucose given as needed. All formulas are an estimate; once initiated, LR fluid input is then titrated based mainly on the urine output; no abrupt change is made at the eighth postburn hour.

reduction in organ perfusion that lasts about 48 hours after burn despite adequate fluid resuscitation. After resuscitation is complete, an increased cardiac output, increased metabolic rate, and catabolic state characterize the "flow" phase of the response to injury. Hypermetabolic responses result in increased body temperature, increasing oxygen requirements and glucose consumption, lipolysis, and proteolysis.[7] This phase lasts until the wounds are permanently closed—and even months after discharge in patients with massive burns. Global immunosuppression, loss of the natural barrier to bacteria normally provided by intact skin, invasive lines, and smoke-injured lungs all predispose to death in the intensive care unit from infectious complications.

RESUSCITATION

There are currently several fluid resuscitation formulas available for use in children; the Parkland, modified Brooke, and Galveston formulas all serve as acceptable approaches to guide initial fluid rates (Table 3). These formulas currently use lactated Ringer's (LR) solution for resuscitation. Conservative fluid management is essential, as overresuscitation will lead to third spacing and the consequences of edema formation, such as abdominal and extremity compartment syndromes, airway edema and respiratory distress, and/or progression of the depth of injury. Hourly monitoring of the urine output and adjustments (titration) of the LR infusion rate up or down to maintain tight control of the urine output in the range 1 to 2 mL/kg per hour (0.5–1.0 mL/kg per hour in big children) are the primary task during burn resuscitation.

Children are especially vulnerable to the body's systemic responses to burn injury. Hypoglycemia, hypothermia, and airway compromise are deadly complications that warrant close monitoring. Children need additional glucose during resuscitation, most conveniently provided as a continuous and constant-rate infusion of 5% dextrose in one-half-normal saline at the maintenance rate, in addition to resuscitation fluids. The resuscitation fluids, for example, LR, are titrated based on urine output; the maintenance fluids, for example, 5% dextrose in one-half-normal saline, are not titrated. (Note, however, that the Galveston formula does not call for the routine inclusion of glucose in the maintenance intravenous line but rather recommends close monitoring of glucose levels in children with burn shock.) Extra care must be taken to protect against hypothermia in young, exposed patients, especially during transport. Dry, sterile dressings and the avoidance of wet dressings are imperative. Finally, patients with circumferential deep burns of the extremities are at risk for extremity eschar syndrome. The tight, inelastic eschar exerts a tourniquet-like effect, which worsens as edema formation takes place. This may progress to arterial occlusion. Elevation of such extremities above the heart, hourly Doppler flow-meter monitoring of distal pulses, prompt burn center consultation, and consideration of escharotomy by a qualified operator are keys to management.

Airway compromise after burns is a real threat, particularly in very young children whose small tracheal dimensions are narrowed significantly by mucosal swelling. Children who receive more than 180 mL/kg of fluid resuscitation are particularly at risk of airway edema. Warning signs of airway issues on presentation in the ED include stridor, hoarseness, drooling, gagging, retractions, and brassy cough, and those with soot staining the nose or mouth are at risk of losing their natural airway. Use of humidified oxygen and racemic epinephrine may help in management before urgently securing the airway with intubation.

Children caught in fires are at risk of carbon monoxide (CO) and cyanide (CN) poisoning produced by partial combustion of cellulosics and synthetic chemicals, respectively. Children are more likely to hide in confined places where oxygen is replaced by dangerous gases. Carbon monoxide binds the hemoglobin molecule in red blood cells more strongly than does oxygen and creates a systemic hypoxemia manifested by neurologic and myocardial dysfunction.[8] A high index of suspicion for children exposed to smoke with neurologic changes, regardless of burn status, should lead clinicians to suspect CO poisoning and to check carboxyhemoglobin levels. Treatment is with 100% oxygen until the carboxyhemoglobin level is less than 5%. In severe cases, hyperbaric oxygen may be needed.[9,10] Diagnosis of CN toxicity may be difficult because (1) symptoms are similar to those of CO poisoning; (2) CN and CO poisoning frequently occur together in fire death victims; and (3) there is no rapid CN assay available. Because CN binds to the terminal cytochrome on the electron transport chain, it interferes with oxygen utilization at the mitochondrial level. Thus, CN patients classically have a high mixed-venous saturation of oxygen (Svo_2) and lactic acidosis, which does not improve with fluid resuscitation. Hydroxocobalamin (high-dose intravenous vitamin B_{12}), a CN chelator, is a rapid and effective antidote. Amyl nitrite and sodium nitrite have the disadvantage of causing methemoglobinemia. Sodium thiosulfate is a catalyst for hepatic degradation of CN, thus has a longer onset of action.

Just as circumferential burns of the extremities can act like a tourniquet, anterolateral burns of the torso can act like a straight-jacket and impair respiration. If not rapidly corrected, this thoracic eschar syndrome may cause cardiopulmonary arrest. Treatment involves rapid bedside thoracic escharotomy: bilateral incisions through the burned skin into underlying fat, extending from the clavicles to the anterior axillary lines, down to the epigastrium, and across the midline.

WOUND MANAGEMENT AND BIOLOGIC DRESSINGS

Minor Burns

The last 2 decades have seen an explosion of options for the treatment of burn wounds. This section will outline a logical approach to selection of topical treatments. Treatment of minor burns (<5% TBSA) can usually be accomplished in the ED with outpatient referral to a primary care physician or surgeon for subsequent care. The mainstay of treatment is cleansing and debridement of sloughing tissue. Broken blisters may be removed with warm water, soap, and coarse-mesh gauze. Intact blisters may be broken or left in place to protect against infection; a rule of thumb described by some authors is to debride large (>2-cm diameter) blisters. Pain management is essential. Minor burns should be treated with a topical antimicrobial, daily dressing changes, and dry nonadherent gauze. Inability to tolerate daily home wound care may necessitate admission. Topical antibiotics such as bacitracin, polymyxin, or silver sulfadiazine can be used on burns of limited extent.[11] An alternative approach is to use a product that can contribute a moist, protective, wound-healing environment. A list of such products is provided in Table 4.

Extensive Burns

With extensive burns, the risk of infection increases, and the focus of topical care shifts to prevention of infection. The traditional topical antimicrobial burn creams are silver sulfadiazine and mafenide acetate. Although bactericidal and relatively painless on application, silver sulfadiazine has some limitations. It promotes the accumulation of proteinaceous exudate on the wound surface and can retard keratinocyte migration and the epithelialization process.[12] Mafenide acetate offers better gram-negative coverage than any other topical agent and has the added benefit of penetration into eschar and cartilage. Thus, it remains the drug of choice for bacterial burn wound infections. It has the disadvantages of pain on application, no antifungal

TABLE 4. Dressings for Treatment of Burns

Type of Dressing	Characteristics	Examples
Hydrocolloid	Forms a gel that makes an adhesive polymer matrix that adheres to the skin	Comfeel (Coloplast) DuoDerm (ConvaTec) CombiDERM
Polyurethane films	Adhesive-coated sheets that are applied directly to the wound	OpSite (Smith & Nephew, Inc) Tegaderm (3M Company)
Hydrogel dressings	Hydrogel dressings are high-water-content gels containing insoluble polymers. Advantages include ability to absorb fluid and aid in wound debridement. Available as an amorphous gel or in sheet form	Amorphous hydrogels: IntraSite (Smith & Nephew) Solugel Sheet hydrogels: Aqua clear Nu-gel (Johnson & Johnson)
Silicon-coated nylon dressings	Made of a flexible polyamide net coated with soft silicone forming a mesh structure that allows drainage of exudate from the burned surface	Mepitel (Mölnlycke Health Care US)
Biosynthetic skin substitutes	Dressings designed to mimic the epidermis or dermis allowing for protection from bacteria, mechanical coverage, and re-epithelialization	Biobrane (Dow Hickam/Bertek Pharmaceuticals) TransCyte (Advanced Tissue Sciences)
Antimicrobial (silver and iodine containing) dressings	Antimicrobial dressings may reduce the risk of infection by minimizing the bacterial colonization of wounds	Silver: Acticoat Silverlon Contreet (hydrocolloid with silver) Avance (foam with silver) Aquacel Ag (ConvaTec) Iodine: Iodosorb
Fiber Dressings	Fiber dressings contain calcium alginate (derived from seaweed) dressings and are absorbent and biodegradable and may allow for the wound to remain moist promoting healing and minimizing bacterial contamination. Alginates can be rinsed away with saline irrigation	Algosteril (Johnson & Johnson) Comfeel Alginate Dressing (Coloplast) CarrasorbH (Carrington Laboratories) Kaltostat (ConvaTec)
Wound dressing pads	Nonadherent dressings, knitted viscose dressings, gauze dressings, or woven cotton pads	Nonmedicated (eg, paraffin gauze dressing) Medicated (eg, containing povidone iodine or chlorhexidine)

Data from Wasiak J, Cleland H, Campbell F. Dressings for superficial and partial-thickness burns [review]. *Cochrane Library* 2010:1–41.

FIGURE 4. An 80% TBSA thermal burn in a child. Biobrane is placed as a temporizing dressing (photo courtesy of John E. Greenwood, MD).

activity, and a risk of metabolic acidosis if used twice daily on extensive wounds (due to absorption of a metabolite, which inhibits carbonic anhydrase in the kidneys). To minimize the adverse effects and maximize the advantages of both agents, the usual practice at several burn centers has been "alternating agents": that is, (1) to perform twice-daily wound care to include thorough cleansing with chlorhexidine gluconate and (2) to alternate mafenide acetate in the morning with silver sulfadiazine in the evening.

Like silver sulfadiazine, the effective component in silver-impregnated dressings is the silver ion. Because these dressings are designed to release silver in a slow fashion, they need to be changed only once every 5 days (approximately). Thus, they are well suited for clean, deep burns of limited extent. Such burns are too deep for biosynthetic skin dressing (see below), but clean enough not to require the frequent dressing changes and additional antimicrobial activity associated with alternating silver sulfadiazine and mafenide acetate (Fig. 4).

Bilaminar Skin Substitutes

Synthetic skin analogs are now available to facilitate healing. Biobrane is a synthetic skin substitute composed of a woven nylon membrane coated with silicone to which collagen is chemically bound.[13] The dressing adheres tightly to partial-thickness burns, preventing fluid losses and protecting against infection. Like donor skin, Biobrane becomes adherent to the fibrin matrix and allows for the growth of fibroblasts. Studies demonstrate that Biobrane performs equally to frozen allografts in coverage of fully excised burn wounds for short periods.[14] Use on superficial partial-thickness wounds in the ED can obviate the need for painful daily dressing changes.[15] Biobrane is a dressing of choice in clean, new partial-thickness burns in the acute setting. Biobrane is elastic and must be placed over a wound without wrinkles and secured in place with staples or adhesive strips. Moisture will retard fibrin bonding, so the product must be kept dry. As Biobrane is relatively susceptible to infection, care must be taken to avoid use in areas with high infection risk, such as contaminated wounds or those with full-thickness eschar.[16] Following application, the wound should be dressed with dry gauze and an elastic bandage or surgical netting; it should then be reinspected in 24 to 48 hours; Biobrane, which is nonadherent and/or which has pus underneath, should then be removed.

TransCyte (previously Dermagraft TC) is similar in construction to Biobrane, with the added feature that it is cultured with newborn human fibroblast cells.[12,17] The human fibroblasts, during growth, secrete various growth factors, which are retained within the meshwork and which may facilitate healing when placed on the burn wound. In addition, its pliability makes it a particularly good option for facial burns.[12]

Biologic Dressings

The term *biologic dressing* refers most commonly to a natural product that is intended to close an open but excised or debrided burn wound, pending a prolonged healing period (for deep partial-thickness burns) or while awaiting autografting (for full-thickness, excised burns). Such materials may be derived from human sources (allograft) or from animal sources (xenograft).[18] Biologic dressings help (1) prevent dessication and bacterial contamination of the open wound, (2) clear residual bacteria from the wound surface, (3) prepare the wound surface for future autografting, and (4) decrease the systemic metabolic response to injury by decreasing local inflammation. No skin substitute has emerged, which is more effective than fresh cadaver allograft skin for this purpose. In the absence of fresh skin, cryopreserved skin is widely used in the United States.[19,20]

Human amnionic membrane, the inner layer of tissue that surrounds the fetus in utero, is "privileged" tissue that does not stimulate rejection. As it contains substantial amounts of growth factors that stimulate epithelial proliferation, human amnion has been used as an effective burn dressing. Because of the risk of disease transmission, fresh specimens have been replaced by cryopreserved, irradiated, or silver-impregnated products. Amnionic membranes are reported to reduce infection and retard evaporative fluid losses and may be used as a dressing in partial-thickness burns.[21,22]

Xenografting, the use of animal skin, has been used for centuries. Porcine xenograft can be effective in retarding water loss, reducing infection, and promoting new epithelial growth. Because porcine xenograft adheres but does not become vascularized, it is useful as a temporary wound covering for partial-thickness burns.

Autografting and Beyond

It is now widely recognized that early surgical excision and grafting have decreased morbidity and improved survival and cosmesis following thermal injury. Particularly in patients with massive (>50% TBSA) burns, the pace of definitive wound closure is limited, however, by the availability of donor sites on the patient's body, such that excision and grafting have to be completed in stages over a period of weeks. The most common approaches to managing this problem are to (1) use cadaver allograft to temporarily close excised wounds until donor sites have healed and can be reharvested and/or (2) use widely meshed (4:1) autograft skin, covered by less widely meshed allograft, as a "sandwich." Newer approaches include dermal regeneration template and cultured keratinocytes.

Integra is a 2-layer product with (1) an inner, collagen-based dermal analog that becomes incorporated by the patient; and (2) an outer, temporary epidermal equivalent made of silicone. Two operations are required. At the first operation, the burn wound is excised, and the Integra is placed. Fourteen to 21 days later, a second operation is performed in which the silicone outer layer is replaced with a thin autograft. It is a product best used at burn centers with extensive institutional experience and training.[22] A demonstration of reduced mortality with this product has been elusive. Cultured keratinocytes are grown in a laboratory from a biopsy obtained from the patient after injury. Although they have a low rate of permanent engraftment, these cells may be lifesaving for selected patients with the most extensive burns.

CASE 1 SUMMARY OF CLINICAL COURSE

The patient was electively intubated. Laboratory testing revealed a carboxyhemoglobin level of 15%, and the patient was placed on 100% oxygen. Total body surface area burn estimation (partial and full thickness) was 25% and arrangement for transfer to a burn center was made. While awaiting transport, the burns were treated with dry sterile dressing, and pain medication was administered as needed.

His weight is estimated at 16 kg. His maintenance fluids would be 52 mL/h (40 mL for the first 10 kg plus 2 mL/kg for additional 6 kg). Using the modified Brooke formula for children, his calculated fluid resuscitation requirements are 75 mL/h. That is, 3 mL $\times$ 16 kg $\times$ 25% = 1200 mL for the first 24 hours, with half given over the first 8 hours. Thus, for the first 8 hours, total fluids to be infused are estimated as 75 mL/h plus 52 mL/h for a total of 127 mL/h. After LR is initiated at the 75-mL/h rate, it is adjusted hourly (up or down) to achieve a target urine output of 1 to 2 mL/kg per hour.

In this article, the authors have presented strategies for managing burn injuries in children in the acute phase including identification of burn severity, estimation of body surface area involvement, and fluid resuscitation calculation and discussed how biologic burn dressings can facilitate the growth of new skin and promote wound healing.

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CME EXAM
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CME EXAMINATION
August 2013

Please mark your answers on the ANSWER SHEET.

Burn Injuries in Children and the Use of Biological Dressings, *Hartstein et al*

1. What is the most common etiology of burns in children younger than 5 years?
   a. chemical
   b. electrical
   c. flame
   d. scalds

2. Although the US Consumer Safety Commission recommends residential water heaters to be set at no more than 120°F, an infant or child may sustain significant burns if left in water at this temperature for how long?
   a. 1 minute
   b. 5 minutes
   c. 10 minutes
   d. 20 minutes

3. A significant cause of burns in children is related to child maltreatment. Which of the following types of burn mechanisms is most concerning for abuse (intentional injury)?
   a. a chemical burn to a 10-year-old in science class
   b. a splash burn from pulling a pot off the stove in a 3-year-old
   c. a curling iron burn to the arm in a 6-month-old
   d. a thermal burn to the right hand in a 2-year-old from touching an open stove

4. A 5-year-old boy (20 kg) sustains 60% TBSA partial-thickness burns from a house fire. He is alert, and there are no signs of airway compromise. According to the Parkland formula, how much resuscitation fluid in addition to maintenance fluids should this child receive in the first 8 hours of the resuscitation?
   a. 500 mL
   b. 1000 mL
   c. 2400 mL
   d. 4800 mL

5. Synthetic skin analogs can be used on which types of burns for children?
   a. clean, new partial-thickness burns
   b. superficial facial burns
   c. deep partial-thickness burns
   d. full-thickness burns

ANSWER SHEET FOR THE *PEDIATRIC EMERGENCY CARE* CME PROGRAM EXAM AUGUST 2013

Please answer the questions on page 946 by filling in the appropriate circles on the answer sheet below. Please mark the one best answer and fill in the circle until the letter is no longer visible. To process your exam, you must also provide the following information:

Name (please print): ______________________

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City/State/Zip ______________________

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Specialty ______________________

1. Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
2. Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
3. Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
4. Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
5. Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ

Your completion of this activity includes evaluating them. Please respond to the following questions below.

Please rate this activity (1 – minimally, 5 – completely)	1	2	3	4	5
Was effective in meeting the educational objectives	○	○	○	○	○
Was appropriately evidence-based	○	○	○	○	○
Was relevant to my practice	○	○	○	○	○

Please rate your ability to achieve the following objectives, both before this activity and after it:
1 (minimally) to 5 (completely)

	Pre 1	2	3	4	5	Post 1	2	3	4	5
1. Manage burn injuries in children in the acute phase including identification of burn severity, estimation of body surface area involvement, and fluid resuscitation calculation.	○	○	○	○	○	○	○	○	○	○
2. Facilitate the rejuvenation of new skin and promote wound healing using biologic burn dressings.	○	○	○	○	○	○	○	○	○	○

How many of your patients are likely to be impacted by what you learned from these activities?
○ <20% ○ 20%–40% ○ 40%–60% ○ 60%–80% ○ >80%

Do you expect that these activities will help you improve your skill or judgment within the next 6 months? (1 – definitely will not change, 5 – definitely will change)	1	2	3	4	5
	○	○	○	○	○

How will you apply what you learned from these activities (mark all that apply):

In diagnosing patients ○
In monitoring patients ○
In educating students and colleagues ○
As part of a quality or peformance improvement project ○
For maintenance of board certification ○
To consider enrolling patients in clinical trials ○
In making treatment decisions ○
As a foundation to learn more ○
In educating patients and their caregivers ○
To confirm current practice ○
For maintenance of licensure ○
Other ______________________

Please list at least one strategy you learned from this activity that you will apply in practice:

How committed are you to applying these activities to your practice in the ways you indicated above? (1 – minimally, 5 – completely)	1	2	3	4	5
	○	○	○	○	○

Did you receive any bias for or againts any commercial products or devices? **Yes** ○ **No** ○
If yes, please explain:

How long did it take you to complete these activities? _______ hours _______ minutes

What are your biggest clinical challenges related to pediatric emergency care?

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CME EXAM ANSWERS
Answers for the Pediatric Emergency Care CME Program Exam

Below you will find the answers to the examination covering the review article in the May 2013 issue. All participants whose examinations were postmarked by August 15, 2013 and who achieved a score of 80% or greater will receive a certificate from Lippincott CME Institute, Inc.

EXAM ANSWERS

May 2013

1. D
2. A
3. B
4. D
5. C